South Kensington was not only closely associated with the early history of general scientific education, but it recapitulates that history. A permanent memorial there to the technical education movement of the 'seventies and 'eighties is the City and Guilds of London Institute for the Advancement of Technical Education. The Institute was formed in 1878 by the Livery Companies of the City of London, one of its principal objects being the establishment of the Central Technical College to supply higher technical education to productive industry. It was designed originally as the coping-stone of a system of technical schools, and particularly for the training of technical teachers. The foundation-stone of the College was laid by the Prince of Wales in 1881, and the building was completed three years later. Its work is now confined to engineering education, and it is one of the largest and best-equipped schools for this subject in the country.

The next important movement, which had for its object the development of teaching and research in applied science, culminated in 1907 in the establishment of the Imperial College of Science and Technology, to which a Royal Charter was granted. The Board of Education transferred to the new governing body of the Imperial College the control of the Royal College of Science and the Royal School of Mines; and the Central Technical College, renamed the City and Guilds (Engineering) College, was also brought into the scheme of common administration. Remarkable progress has since been made in developing the resources of the colleges for teaching and research. A new building has been erected for the Royal School of Mines, and an extension (provided by the Goldsmiths' Company) of the City and Guilds College and others for botany, plant physiology and pathology, and chemical technology, while the social needs of the students have been met by the provision of a special building for the Imperial College Union.

The foregoing list by no means exhausts the buildings at South Kensington. The Natural History Museum (a branch of the British Museum) is in grey terra-cotta, built to the designs of Alfred Waterhouse, and was finished in 1880. It is both a museum and a centre for natural history study and research. The Royal College of Music, a less austere enterprise, was built by Sir Arthur Blomfield and opened in 1894; and the Royal School of Art Needlework and the headquarters of the Royal Geographical Society in Kensington Gore must also be mentioned.

Some final reflections. First and most obvious, the available space at South Kensington is now practically exhausted. Almost the only science which has not been practised at South Kensington is town planning, and there can be no doubt that the area might have been planned more economically. Much still remains to be done in providing new departments of pure and applied science. Under no possible re-organisation of higher education in the metropolis can South Kensington cease to be a most important centre for education and research in science and art. It has great resources in traditions, in men, in materials; and if, like Oxford, it is already the home of some lost causes, it has a marvellous power of adapting itself to new conditions.

Dark Nebulæ.[1]

By Prof. H. N. RUSSELL, Mount Wilson Observatory.

IT is now generally believed that many of the dark markings in the Milky Way, and dark starless regions in the sky, are produced by the interposition of huge obscuring clouds between us and the more remote stars. A long list of such dark markings has been given by Barnard,[2] who has done more than anyone else to point out their importance and probable nature. In some cases, as in the Pleiades, Orion, and Ophiuchus, these "regions of obscuration" merge into faintly luminous nebulosity in the vicinity of certain stars, in such a way that there can be no doubt that they lie near these stars in space.

It thus appears that the obscuring masses or dark nebulæ in Ophiuchus and Scorpius are at a distance of 100 to 150 parsecs, those in Taurus at probably about the same distance, and those in Orion some 200 parsecs from us, while the dimensions of the individual clouds are themselves measured in parsecs.

The occurrence of these three great regions of obscuration within a distance which is so small compared with that of the galactic clouds indicates that such objects are probably of great cosmical temperature.

These dark nebulæ usually appear to be quite opaque. In some cases the stars can be seen faintly through them, apparently without much change in colour; but in some examples[3] stars imbedded in dense luminous nebulosity are abnormally red.

Of the various forms in which matter may be distributed in space, by far the most efficient in producing obscuration is fine dust, since this has the greatest superficial area per unit of mass. In a cloud composed of spherical particles of radius r and density ρ, distributed at random so that the average quantity of matter per unit volume is d, the extinction of a beam of light in passing through this cloud will be e stellar magnitudes per unit of distance, where $e = 0{\cdot}814\, qd/\rho r$. The numerical factor is independent of the physical units which are employed. The factor q is introduced to take account of the complications which occur when the size of the particle becomes comparable with the wave-lengths of light.[4] For particles more than two or three wave-lengths in diameter q is sensibly equal to unity. For smaller particles it increases and is a maximum, 2·56, when the circumference of the particle is 1·12 times the wave-length. It then rapidly diminishes and becomes nearly equal to $14/3 \times (2\pi r/\lambda)$ for particles of less than half this diameter.[5] The ratio

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[1] Communication to the National Academy of Sciences, Washington, on March 14. Reprinted from the Proceedings of the Academy, vol. 8, No. 5, May 1922.

[2] Barnard, E. E., *Astrophys. Journ., Chicago*, 49, 1919 (1-23).

[3] Seares, F. H., and Hubble, E. P., *ibid.*, 52, 1920 (8-22); *Mt. Wilson Contr.*, No. 187.

[4] Schwarzschild, K., "Sitzungsberichte der K. B. Akad. der Wiss.," *Math.-Phys. Kl., München*, 31, 1901 (293-338); Proudman, *Monthly Not., R.A.S., London*, 73, 1913 (535-539).

[5] Barnard, E. E., *Astrophys. Journ., Chicago*, 38, 1913 (496-501).

q/r is a maximum, 2·42, when the circumference equals the wave-length.

For clouds of the same mean density d the opacity reaches a sharp maximum when the particles are of this size. At the same time the absorption changes from the non-selective type to the selective type, varying as λ^{-4}. For visual light the maximum opacity occurs when the radius is 0·086 ρ. A cloud of particles of this size, and of the density of rock (2·7), will exert an absorption of one magnitude if it contains only 1/86 of a milligram of matter per square centimetre of cross-section, regardless of its thickness. If the particles are of half this size, or smaller, the selective absorption is almost as complete as for a gas, but may be nearly 100 million times as great.

Obscuration of light in space, therefore, whether general or selective with respect to wave-length, will be produced mainly by dust particles a few millionths of an inch in diameter, unless such particles form a negligible proportion by weight of the obscuring cloud.

It is just these particles, however, which will be most influenced by the pressure of the radiation of the stars. Calculations from more accurate data confirm Schwarzschild's conclusion that for a particle of the optimum size and the density of water, the repulsive force of the sun's radiation is about ten times the gravitational attraction, and also show that for stars of the same brightness, but other spectral types, the radiation pressure will be about two-thirds as great for Class M and increase for the whiter stars, till for Class B it is fully ten times as great as for solar stars.

Dwarf stars will scarcely repel dust at all, but giant stars, and especially the very luminous one of Class B, will repel it very powerfully. Only the coarser particles can come near such a star—the finer ones being driven away. This selective removal, from the vicinity of bright stars, of the particles which are most efficient in cloud formation, may explain the fact that the luminous portions of these dark nebulæ, though centred upon stars, do not brighten up in their immediate neighbourhood so much as might have been anticipated.

The finest dust must continue to be repelled by the stars, whatever their distance. It may congregate to some degree in interstellar regions, where the repulsive forces from stars on opposite sides are nearly equal, but it can be in no true equilibrium there, and must escape ultimately to an indefinitely great distance.

Some force, however, operates to hold these dark clouds together, for their outlines are often sharp. This is probably the gravitational attraction of the cloud itself.

Taking a spherical cloud as an example we find that, if its mass is M times that of the sun, and its radius R parsecs, the velocity of escape at the surface is 0·092 $M^{\frac{1}{2}} R^{-\frac{1}{2}}$ km./sec. The internal velocity of the nebular material is known only in the case of the Orion nebula, where the luminous gas shows irregular variations in radial velocity from point to point, amounting to about 5 km./sec. on each side of the mean.[6]

For a nebula 1 parsec in diameter (which may be taken as a rough representation of the small black, almost round spot about 15′ in diameter, discovered by Barnard[7] in Ophiuchus) the mass must be 60 times that of the sun, if the escape velocity is to be 1 km./sec.

If all this matter were in the form of particles of rock of the optimum size, the extinction for light passing centrally through the cloud would be 2000 magnitudes. An extinction of 10 magnitudes (quite sufficient for opacity) would be produced if the radii of the particles were 72 μ.

Though these numerical values are largely conjectural, it appears probable that the aggregate mass contained in one of these great obscuring clouds must be very considerable—probably sufficient to form hundreds of stars—and that a sensible fraction of the whole mass must be in the form of dust less than 0·1 mm. in diameter.

It can easily be shown that any dust cloud which is impervious to light must also be impervious to particles such as those of which it is composed (and to free-moving electrons as well) in the sense that such a particle could not traverse the cloud without a practical certainty of collision. These collisions may account for the existence of dust within the clouds, even if it was not a primitive constituent.

The transition from these dark nebulæ to luminous nebulæ in the vicinity of the stars appears to occur in two ways. The first is by simple reflection of the light of the stars: this appears to occur in the nebulosity surrounding the Pleiades, the star ρ Ophiuchi, and probably in many other cases. The second is by the excitation of gaseous emission, as in the Great Nebula of Orion, which is connected with one of the greatest known regions of obscuration and itself shows signs that obscuring masses lie in front of it.

Both theoretical considerations, as suggested by the writer[7] and the facts of observation collected by Hubble,[8] indicate that the luminosity of gaseous nebulæ is probably due to excitation of the individual atoms by radiations of some sort (aethereal or corpuscular) emanating from neighbouring stars of very high temperature. In the Orion nebula the stars of the Trapezium (θ Orionis) appear to be the source of excitation.

There is no reason to believe that the luminous gas forms the whole, or even any large part, of the matter present within the region—only that it is selectively sensitive to the incident excitation, and therefore gives out most of the light, just as the gases (carbon compounds and nitrogen) do in the coma and tail of a comet.

If the turbulent motions of the various parts of this nebula are of the same order of magnitude in the other two co-ordinates as in the radial direction, they must correspond to an average proper motion of 1·5 astronomical units per year, or about 0″·8 per century (with Kapteyn's parallax of 0″·0055). In a million years this would carry a nebulous wisp through 2°, which is more than the whole extent of the nebula.

It appears probable, therefore, that the aspect of the Orion nebula was entirely different a million years ago from what it is now, as regards its details. There is no reason, however, to suppose that the nebula was not there. We may rather imagine that wisps and clouds of dust, carrying gas with them, are slowly drifting about. Some of them pass through the field of excitation due to the radiations from the Trapezium stars, and, when in this field, the gas is set shining—faintly near its outskirts, and without excitation of the nebular lines; more strongly, and with the nebular lines, near the middle.

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[6] "Publications of the Lick Observatory, Berkeley, Cal.," 13, 1918 (98).

[7] Russell, H. N., *The Observatory*, London, 44, 1921 (72).

[8] Hubble, E. P., "Annual Report of the Mount Wilson Observatory," 1921; "Year Book of the Carnegie Institution of Washington," 1921.

According to unpublished investigations by Hubble, it appears probable that the absorbing clouds in Orion, not far from the nebula, weaken the light of stars behind them by at least ten magnitudes. The exciting radiations probably penetrate to a relatively small depth into the mass and, even if they went deeper, little of the excited light could get out again. The Orion nebula, on this hypothesis, may be regarded almost as a superficial fluorescence of the gaseous portion of this vast dark cloud, in the limited region where it is stimulated by the influence of the exciting stars.

The Corrosion of Ferrous Metals.

THE fact that iron readily perishes when exposed to the forces of Nature must have been observed by man practically as long as the metal itself has been recognised. But it is only comparatively recently that the problem of the preservation of iron from corrosion has developed into one of such stupendous economic importance as at the present day. Sir Robert Hadfield estimates the wastage of the world's steel on account of rust alone to reach some 29 million tons for the year 1920. This, at an average figure of 20*l.* per ton, represents a loss to the community of at least 580,000,000*l.* One interesting feature of this calculation is that the annual increase in the world's total stock of iron and steel is only some 30 per cent. of the annual production, the remaining 70 per cent. being absorbed in replacing wastage consequent upon fair wear and tear and upon corrosion.

In a paper read before the North-East Coast Institution of Engineers and Shipbuilders in April last, Mr. A. Pickworth most opportunely directs the attention of marine engineers to this aspect of the subject. It is pointed out that the repairs necessary to counteract the ravages of rusting during ten years' service in the case of a single battleship have, for structural work alone, been known to cost some 150,000*l.* Any one, therefore, who can assist in combating this destructive plague to iron and steel merits the gratitude of the community.

It is now well recognised that, in addition to air, the presence of liquid water is essential to corrosion. Rise of temperature accentuates the evil, the rate of oxidation of iron immersed in water at 80° C. being more than seven times as great as that at 0° C. It is easy, therefore, to offer an explanation, as Mr. Pickworth points out, for the fact that corrosion assumes more serious proportions in the vicinity of boiler-room tanks on steamers than elsewhere. The tanks, whether used for ballast or feedwaters, are alternately filled and more or less completely emptied, but are rarely, if ever, thoroughly dry, for obvious reasons. The residual moisture, coupled with unequal distribution of waste heat from the boilers, and erratic cooling from the floor and shell plating in contact with the sea under the vessel, results in rapid corrosion. The steel work of the bunkers of a vessel frequently requires patching or renewing on account of corrosion. This is particularly the case with pocket bunkers at the sides of the boilers or 'tween-deck bunkers above the boilers. Not only does the heat from the boilers and the moisture in the coal tend to produce a corrosive atmosphere, but the abrasive action of the coal as it enters from the shoots and while it is settling as the lower layers are worked out all tend to accentuate the destruction of the metal. In practice it is found that the lower parts of the bunkers are the most seriously affected, and this is attributed to the accumulation of a mixture of small coal and mud which is rarely removed except at special surveys. Although in exceptional cases the outside surfaces of the shell plating of a ship may be seriously pitted and corroded, as, for example, when the vessel has been lying in very foul waters, the general rule appears to be for the wastage to be greater on the inside surfaces. This is due, in the main, to the extra cleaning and general attention received by the outside surfaces. Special care should be paid to those portions of the inside shell immediately under the sidelights, for the constant trickling of rain or water of condensation from the glass induces most serious corrosion, resulting at times in actual perforation of the plating.

As might be expected, the most serious external corrosion of the shell plating occurs in the neighbourhood of the wind and water line, the metal being alternately drenched and exposed to air. The surface water also is in motion relatively to the plates, and this tends to stimulate corrosion. One interesting point deserving of consideration is the fact that the external portions of a vessel above the water-line receive deposits of sodium chloride in consequence of the evaporation of sea spray. Owing to the hygroscopic character of the deposit, as well as to its chemical activity, corrosion is readily induced thereby.

It is difficult to obtain trustworthy comparative data on the relative efficiencies of different methods of avoiding corrosion. Early man frequently surrounded his iron with copper or bronze, so that his implements might possess the strength of the former combined with the incorrodibility of the latter metal. Modern developments of this process are galvanising, tinning, electroplating, and the like. The Bower-Barff process consists in coating the iron or steel with magnetic oxide, which is an excellent protection so long as it remains unbroken. The metal is cleaned, heated in a closed chamber by means of producer gas, and finally oxidised in a current of superheated steam for a couple of hours. If, however, the resulting coat of oxide should crack or chip off at any point, the layer of unprotected metal thereby exposed is rapidly attacked. The oxide functions as cathode and the metal as anode, so that deep pitting ensues. Mr. Pickworth mentions that a certain shipowner, relying on the protective action of mill scale, gave instructions for a ship to be built, the shell plates of which were to retain their mill scale as completely as possible. For a time all went well on service, but suddenly the vessel developed leaks and was almost lost. Upon docking it was found that many of the plates had been deeply pitted and even perforated in a number of places where the mill scale had been destroyed either during construction or through